

REMARKS

This is intended as a full and complete response to the Final Office Action dated April 8, 2008, having a shortened statutory period for response set to expire on July 8, 2008. Please reconsider the claims pending in the application for reasons discussed below.

Claims 1-2, 4-7, 9-14, 16-17, 19-20, 22-25, 27-28, 30-33, 35-38, 40-42, 44-46, 48-51, and 53-67 remain pending in the application and are shown above. Claims 1-2, 4-7, 9-14, 16-17, 19-20, 22-25, 27-28, 30-33, 35-38, 40-42, 44-46, 48-51, and 53-67 stand rejected by the Examiner. Reconsideration of the rejected claims is requested for reasons presented below.

The Applicant notes that the RCE was filed on January 14, 2008 in response to the Office Action dated October 16, 2007, because the Office Action Summary sheet contained a checked final box and an unchecked non-final box. Also, the Image File Wrapper and the pending status on PAIR both referred to the Office Action as FINAL. The Applicant appreciates the Examiner entering the Request and accompanying amendments as a Response.

Claims 1-2, 4-7, 9-14, 16-17, 19-20, 22-25, 27-28, 30-33, 35-38, 40-42, 44-46, 48-51, and 53-67 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over *Aaltonen et al.*, U.S. Pub. No. 2003-0165615, herein *Aaltonen*, in view of *Kawano et al.*, U.S. Pat. No. 6,605,735, herein *Kawano*. The Examiner asserts it would have been obvious to modify *Aaltonen* to include the precursors of *Kawano* in order to use a precursor that gives the benefit of low temperature deposition and ease of supply. The Examiner further asserts it would have been obvious to use CVD precursors in an ALD process. Also, the Examiner further asserts that since the specification states "traditional reductants" – that the Applicant admits such reducing agents are "well-known and documented in the prior art." (FOA, page 5). The Applicant respectfully traverses the rejection and these assertions.

Aaltonen discloses forming ruthenium films by using oxidizers during an ALD process. The background of *Aaltonen* discloses a CVD process which uses bis(cyclopentadienyl) ruthenium and oxygen to form a ruthenium film. "However, carbon and hydrogen were incorporated as harmful impurities in the deposited films, thus increasing the resistivity of the film." (paragraph 0012). *Aaltonen* further teaches "the general limitations of the CVD method, such as problems related to achieving good large area uniformity and accurate thickness control, still remain. In addition, it is hard to obtain good step coverage and high film purity at the same time." (paragraph 0012). *Kawano* discloses processes to synthesize ruthenium precursors and then use such precursors in CVD process, such as thermal-CVD, plasma-CVD, or photo-CVD. (col. 12, lines 1-2). The Examiner has not provided evidence to why the skilled artisan would be motivated to combine *Aaltonen*, which teaches against CVD processes, with *Kawano* which teaches only CVD processes.

Also, *Aaltonen* teaches the surprising result of using oxygen gas as a reducing agent to form a metallic film by an ALD process. *Aaltonen* states:

Surprisingly we have now found that oxygen, in particular oxygen in molecular form, **is capable of reducing noble metal compounds into elemental form. High, quality metal thin films can be deposited by utilizing reactions between the metal precursor and oxygen. This is surprising, since oxygen is usually considered an oxidizing source chemical in ALD** and even as such an agent its reactivity is usually only modest at temperatures below 500°C. (paragraph 0019).

Therefore, *Aaltonen* utilizes oxygen as a reducing agent in order to produce the desirable pure metals during an ALD process.

Conversely, *Kawano* utilizes oxygen as an oxidation gas in order to produce metal oxides during a CVD process. "**Oxygen was employed as an oxidation gas**" and "Ru film was obtained **at the oxygen flow rate of 0 sccm** (A), while RuO₂ films were obtained **at the oxygen flow rate of larger than 0 sccm** (B) or (C). Namely, it has been found out that either an Ru film or an RuO₂ film can be produced by controlling the oxygen flow rate in the CVD." (col. 14, lines 40-56).

Therefore, the skilled artisan would not be motivated to combine *Aaltonen* with *Kawano*, since *Aaltonen* teaches using oxygen to form metallic ruthenium films by ALD, and *Kawano* teaches using oxygen to form ruthenium oxide films by CVD as well as the necessity to omit oxygen in order to form metallic ruthenium films during CVD.

Additionally, the Examiner admits that *Aaltonen* does not disclose the claimed ruthenium precursors. Therefore, the Examiner relies upon *Kawano* for ruthenium precursors. The Examiner asserts *Kawano* "teaches using the ruthenium compounds claimed as shown in column 3 line 39- column 4 line 12 in CVD." (FOA, page 4). The Applicant respectfully disagrees that *Kawano* teaches the claimed precursor used in CVD.

Kawano discloses "the present invention provides a **half-sandwich organometallic ruthenium compound** characterized by being represented by the following general formula (1)," and thereafter provides such chemical structure. (col. 3, lines 39-52). The half-sandwich organometallic ruthenium compounds of formula (1) are used in the CVD processes. *Kawano* further discloses the "present invention further provides a process characterized by **reacting an open ruthenocene** represented by the following general formula (3)" which is "**in a solvent in the presence of** zinc with a cyclopentadiene represented by the following general formula (4)" "**to thereby produce a half-sandwich organometallic ruthenium compound** represented by the general formula (1)." (col. 3, line 65, to col. 4, line 25). *Kawano* uses the open ruthenocene of formula 4 as a chemical precursor during the synthesis of the half-sandwich organometallic ruthenium compound of formula 1. The half-sandwich organometallic ruthenium compound is used for CVD, not the open ruthenocene. Therefore, *Kawano* does not teach using the claimed ruthenium compounds for CVD, as asserted by the Examiner.

Also, the Applicant respectfully disagrees with the Examiner construing the term "traditional reductants" as being well-known and documented in the prior art. The claimed method, including the reducing gas, is novel and non-obvious.

Therefore, *Aaltonen* and *Kawano*, alone or in combination, do not teach, show, or suggest a method for forming a ruthenium material on a substrate surface, comprising

positioning a substrate within a process chamber, exposing a ruthenium-containing compound to the substrate while forming a ruthenium-containing compound film thereon, wherein the ruthenium-containing compound is selected from the group consisting of bis(dialkylpentadienyl) ruthenium compounds, bis(alkylpentadienyl) ruthenium compounds, bis(pentadienyl) ruthenium compounds, and combinations thereof, purging the process chamber with a purge gas, exposing a reducing gas comprising ammonia and atomic hydrogen to the ruthenium-containing compound film on the substrate while forming a ruthenium layer thereon, and purging the process chamber with the purge gas, as recited in claim 1, and claims dependent thereon.

Also, *Aaltonen* and *Kawano*, alone or in combination, do not teach, show, or suggest a method for forming a ruthenium material on a substrate surface within a process chamber, sequentially comprising exposing a substrate to bis(2,4-dimethylpentadienyl) ruthenium to form a ruthenium-containing film on the substrate, purging the process chamber with a purge gas, exposing a reducing gas comprising ammonia to the ruthenium-containing film while forming a ruthenium layer thereon, and purging the process chamber with the purge gas, as recited in claim 11, and claims dependent thereon.

Also, *Aaltonen* and *Kawano*, alone or in combination, do not teach, show, or suggest a method for forming a ruthenium material on a substrate, comprising depositing a barrier layer on a substrate during a first ALD process, wherein the barrier layer comprises a material selected from the group consisting of tantalum, tantalum nitride, tantalum silicon nitride, titanium, titanium nitride, titanium silicon nitride, tungsten, tungsten nitride, and combinations thereof, and exposing the substrate sequentially to a ruthenium-containing compound and a reducing gas comprising ammonia to form a ruthenium layer on the barrier layer during a second ALD process, wherein the ruthenium-containing compound is selected from the group consisting of bis(dialkylpentadienyl) ruthenium compounds, bis(alkylpentadienyl) ruthenium compounds, bis(pentadienyl) ruthenium compounds, and combinations thereof, as recited in claim 19, and claims dependent thereon.

Also, *Aaltonen* and *Kawano*, alone or in combination, do not teach, show, or suggest a method for forming a ruthenium film on a dielectric material disposed on a

substrate surface, comprising positioning a substrate comprising a dielectric layer thereon within a process chamber, exposing a ruthenium-containing compound to the dielectric layer while forming a ruthenium-containing compound film thereon, wherein the ruthenium-containing compound is selected from the group consisting of bis(dialkylpentadienyl) ruthenium compounds, bis(alkylpentadienyl) ruthenium compounds, bis(pentadienyl) ruthenium compounds, and combinations thereof, purging the process chamber with a purge gas, exposing a reducing gas comprising ammonia to the ruthenium-containing compound film on the dielectric layer while forming a ruthenium layer thereon, and purging the process chamber with the purge gas, as recited in claim 27, and claims dependent thereon.

Also, *Aaltonen* and *Kawano*, alone or in combination, do not teach, show, or suggest a method for forming a ruthenium material on a substrate surface, comprising positioning a substrate within a process chamber, exposing the substrate to a ruthenium-containing compound comprising ruthenium and at least one open chain dienyl ligand while forming a ruthenium-containing compound film thereon, purging the process chamber with a purge gas, exposing the ruthenium-containing compound film to a reducing gas comprising ammonia and hydrogen gas while forming a ruthenium layer on the substrate, and purging the process chamber with the purge gas, as recited in claim 36, and claims dependent thereon.

Also, *Aaltonen* and *Kawano*, alone or in combination, do not teach, show, or suggest a method for forming a ruthenium material on a low-k material disposed on a substrate surface, comprising positioning a substrate comprising a low-k layer disposed thereon within a process chamber, heating the substrate to a temperature within a range from about 200°C to about 400°C, exposing the low-k layer to a ruthenium-containing compound comprising ruthenium and at least one open chain dienyl ligand while forming a ruthenium-containing compound film thereon, purging the process chamber with a purge gas, exposing the ruthenium-containing compound film to a reducing gas comprising ammonia while forming a ruthenium layer on the low-k layer, and purging the process chamber with the purge gas, as recited in claim 44, and claims dependent thereon.

Also, *Aaltonen* and *Kawano*, alone or in combination, do not teach, show, or suggest a method for forming a ruthenium material on a low-k material disposed on a substrate surface, comprising positioning a substrate comprising a low-k layer disposed thereon within a process chamber, heating the substrate to a temperature within a range from about 200°C to about 400°C, exposing the low-k layer to bis(2,4-dimethylpentadienyl) ruthenium to form a ruthenium-containing compound film thereon, purging the process chamber with a purge gas, exposing the ruthenium-containing compound film to a reducing gas comprising ammonia and atomic hydrogen while forming a ruthenium layer on the low-k layer, and purging the process chamber with the purge gas, as recited in claim 54, and claims dependent thereon.

Also, *Aaltonen* and *Kawano*, alone or in combination, do not teach, show, or suggest a method for forming a ruthenium material on a barrier material layer disposed on a substrate surface, comprising positioning a substrate comprising a tantalum-containing barrier layer disposed thereon within a process chamber, heating the substrate to a temperature within a range from about 200°C to about 400°C, exposing the tantalum-containing barrier layer to bis(2,4-dimethylpentadienyl) ruthenium while forming a ruthenium-containing compound film thereon, purging the process chamber with a purge gas, exposing the ruthenium-containing compound film to a reducing gas comprising ammonia and atomic hydrogen while forming a ruthenium layer on the tantalum-containing barrier layer, and purging the process chamber with the purge gas, as recited in claim 55, and claims dependent thereon.

Withdrawal of the rejection is respectfully requested by the Applicant.

In conclusion, the references cited by the Examiner, alone or in combination, do not teach, show, or suggest the claimed invention.

Having addressed all issues set out in the Final Office Action, the Applicant respectfully submits that the claims are in condition for allowance and respectfully request that the claims be allowed.

Respectfully submitted,



John-Paul F. Cherry
Registration No. 57,323
PATTERSON & SHERIDAN, L.L.P.
3040 Post Oak Blvd., Suite 1500
Houston, TX 77056
Telephone: (713) 623-4844
Facsimile: (713) 623-4846
Agent for the Applicant